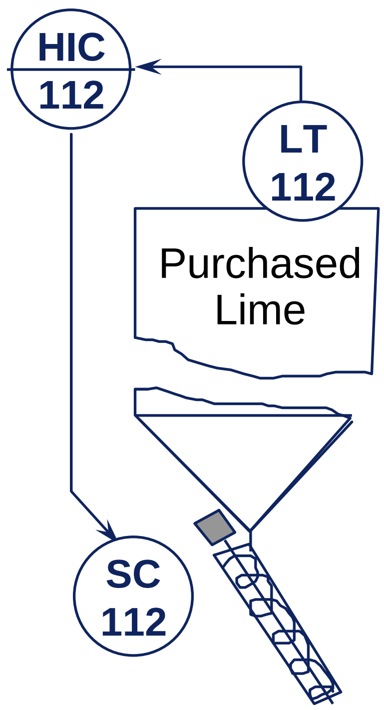
Manual and Feedback Control

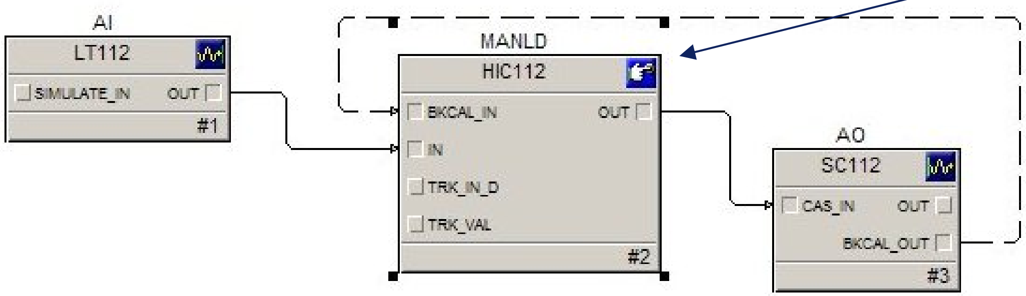
Manual Control

- If a process has no load disturbances or their affect on the controlled parameter is negligible, then the process may be manually controlled
- For this case, manual control i.e. hand-indication-control, HIC, is sufficient since the controlled parameter will remain constant as long as the manipulated parameter is not changed.
- A manual loader is used to allow the manipulated parameter may be adjusted by the plant operator based on an indicated value of the controlled parameter.

Example - Hand Indicator Controller

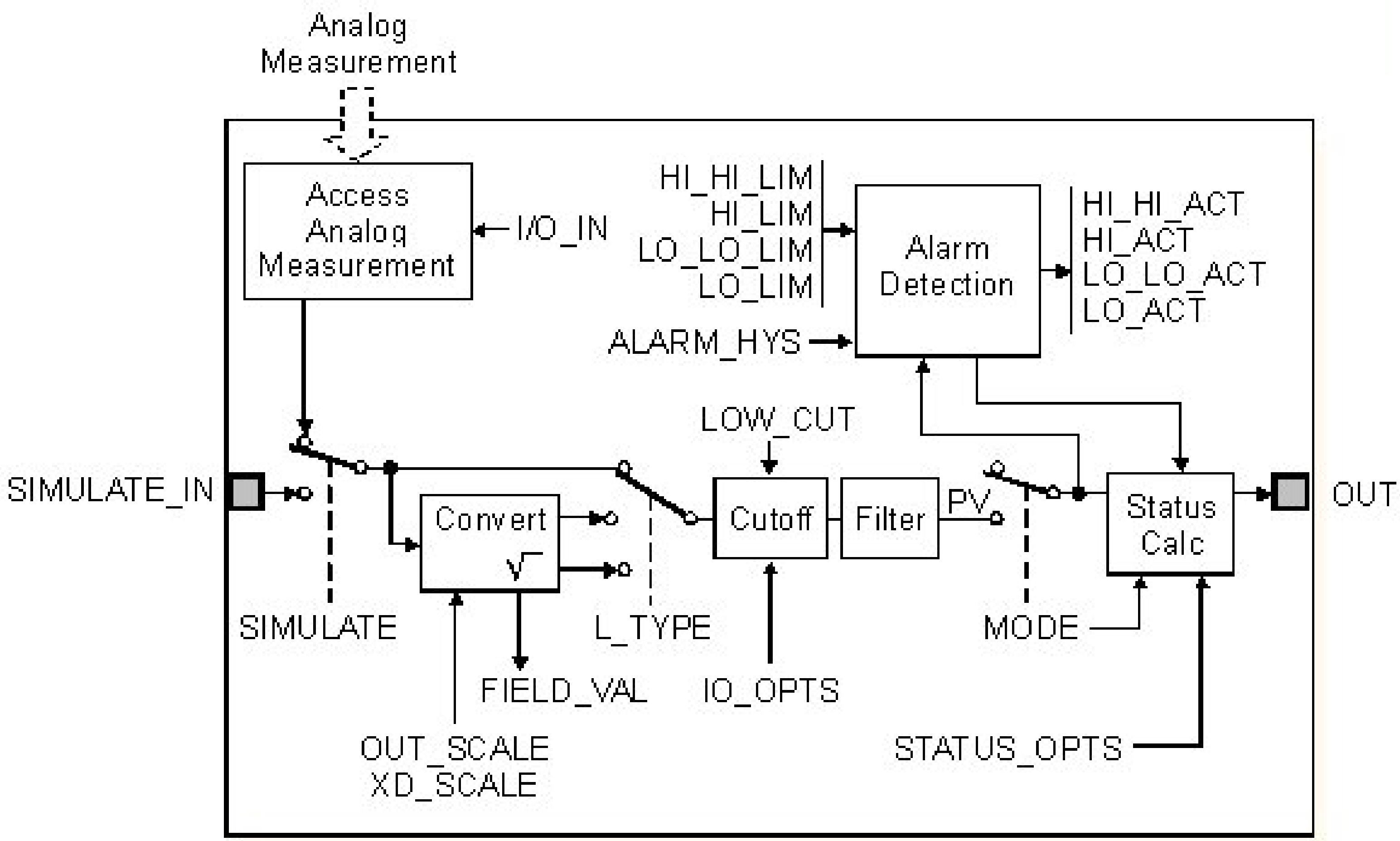


Hand Indicator Controller - DeltaV

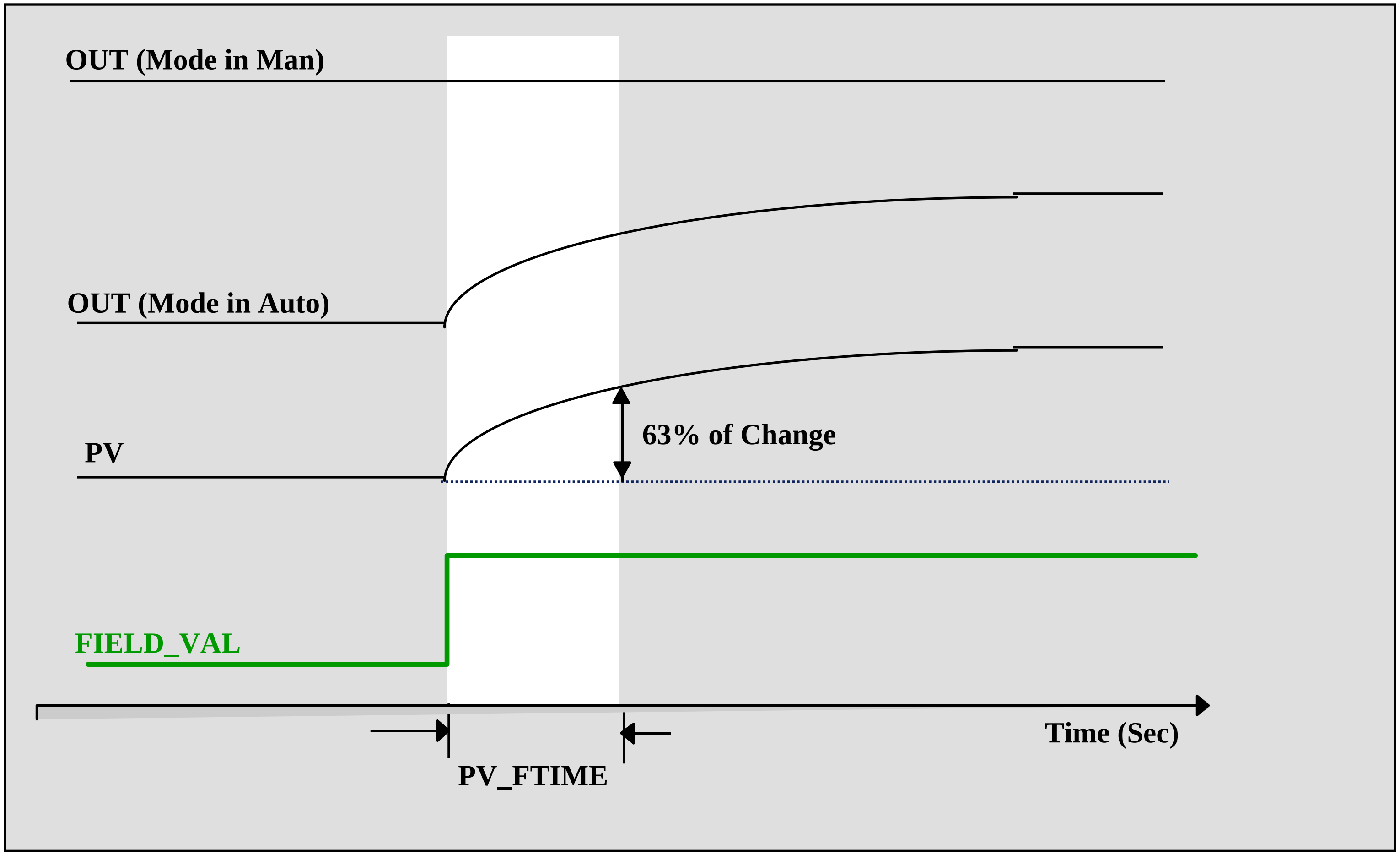


- The manual loader block is used in DeltaV for Hand Indication Control (HIC)
- The AI block may be used to provide an indication that is helpful to the operator in making manual adjustments.
- Designed to work with the AO block for interface to the final control element.

Analog Input Block



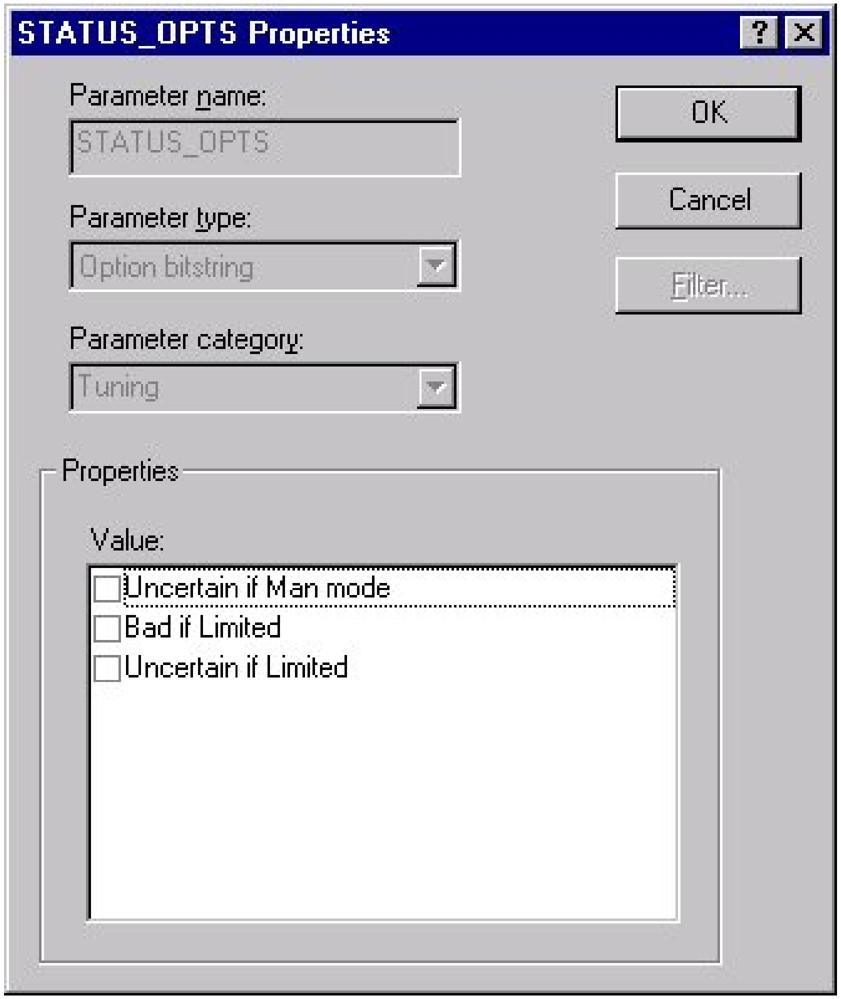
Measurement Filtering



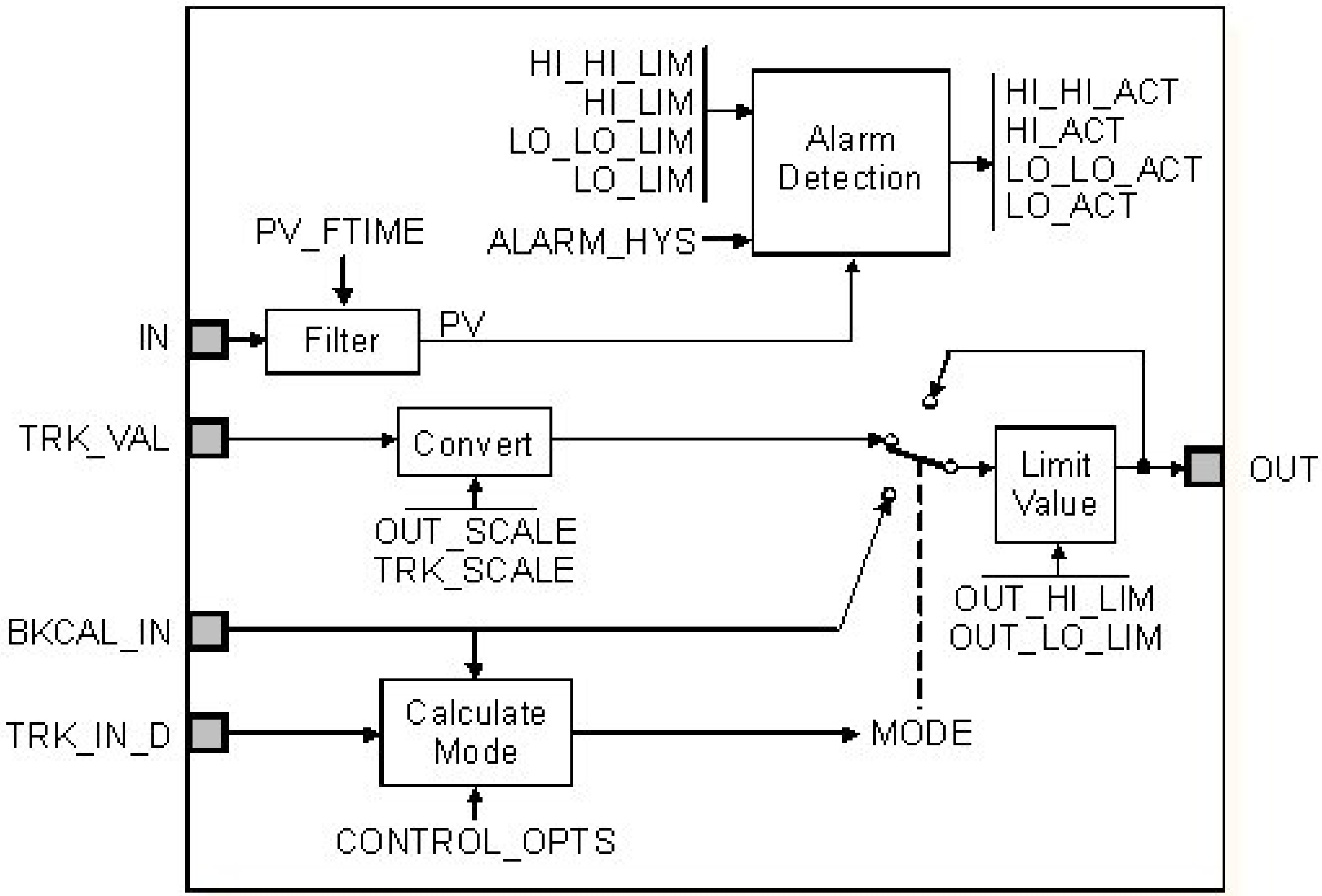
Status Provided by the Analog Input

- The status quality will be set to BAD if the measurement exceeds the A/D range (open or short condition) or the block is in Out-of-Service Mode.
- High or low limit is set in status if the measurement exceeds the over-range and under-range values specified for the channel
- A status quality of Uncertain or BAD may be created under limit conditions or Man Mode based on STATUS_OPT parameter selections.

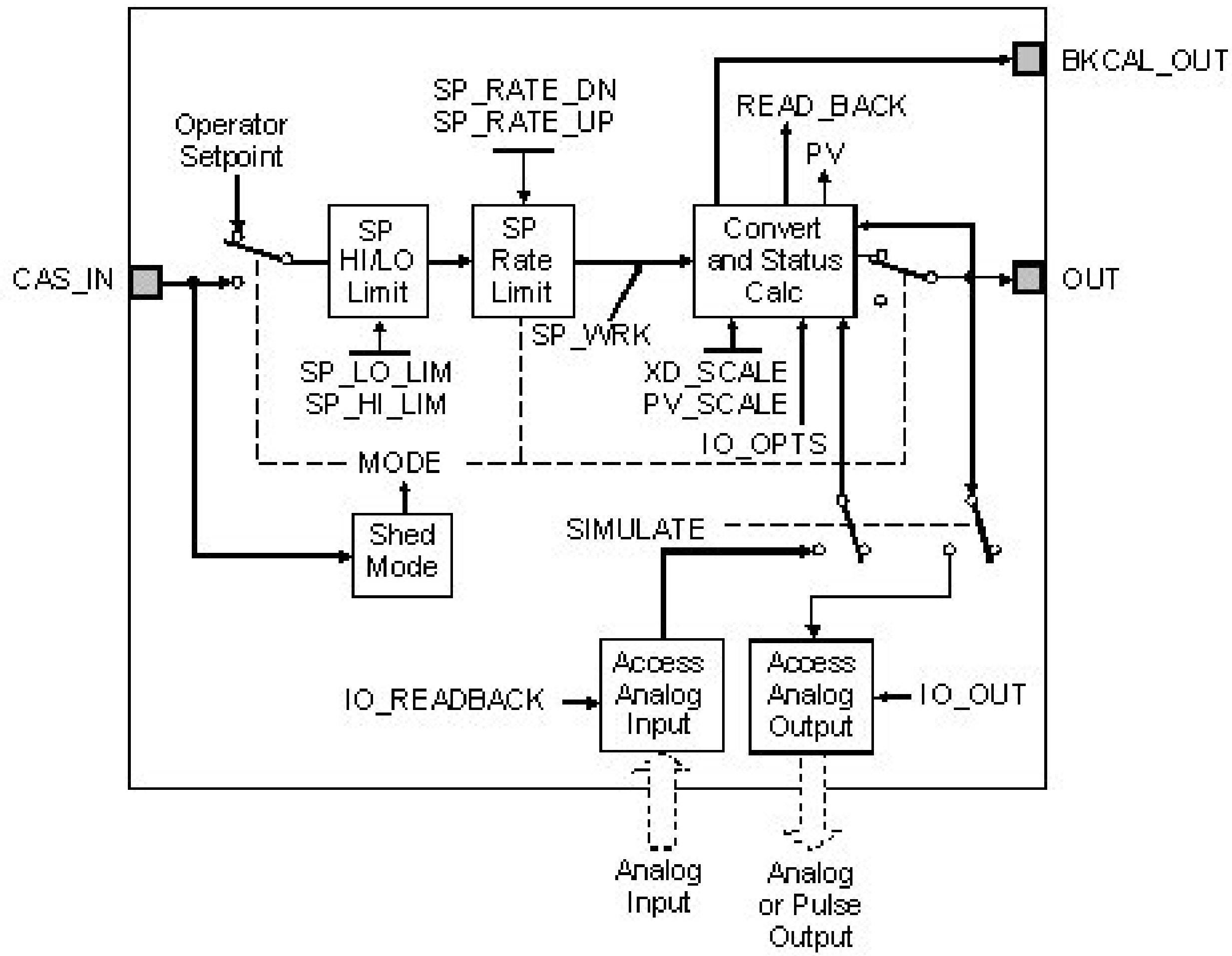
AI Status Options



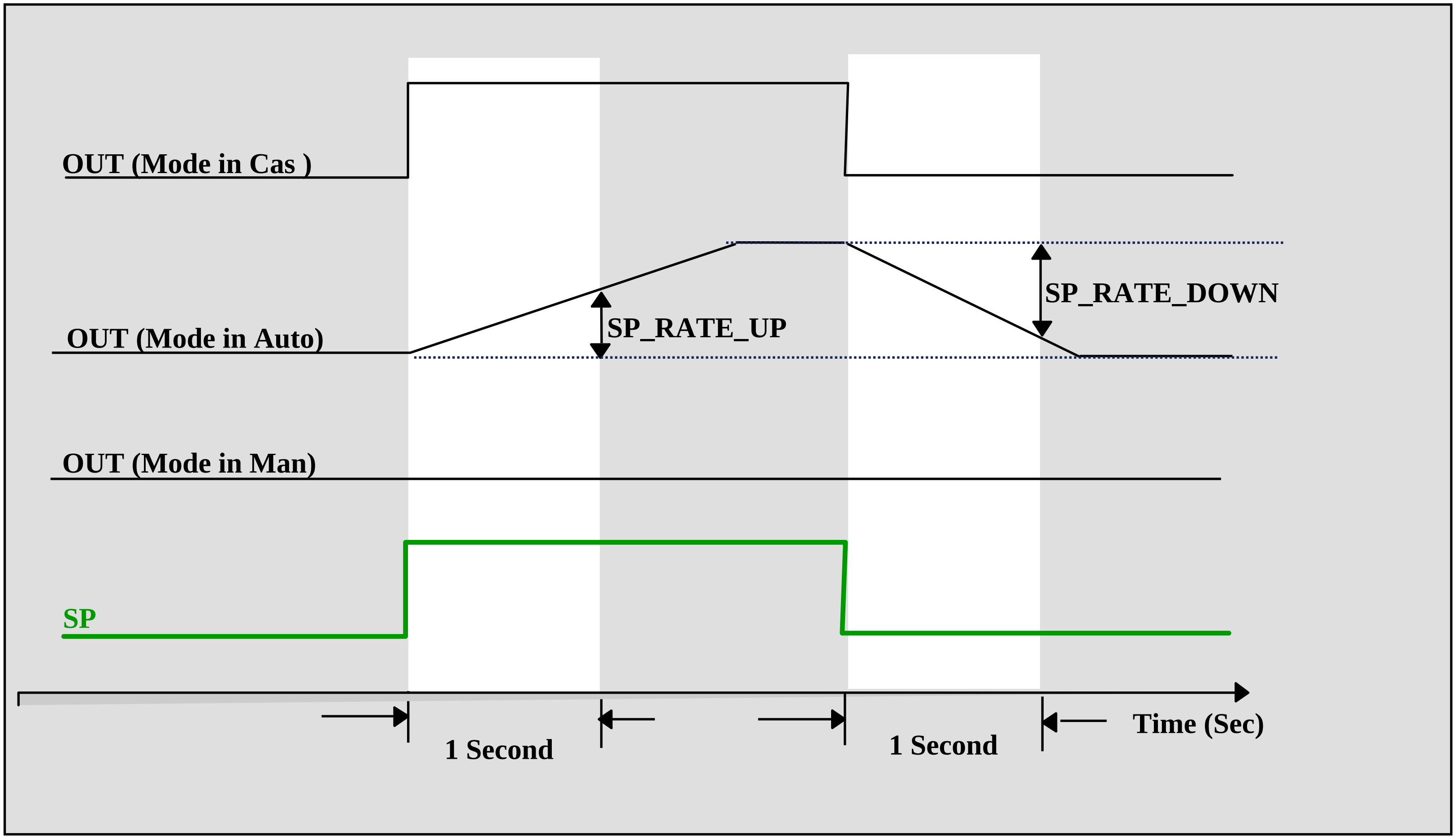
Manual Loader Function Block



Analog Output Block



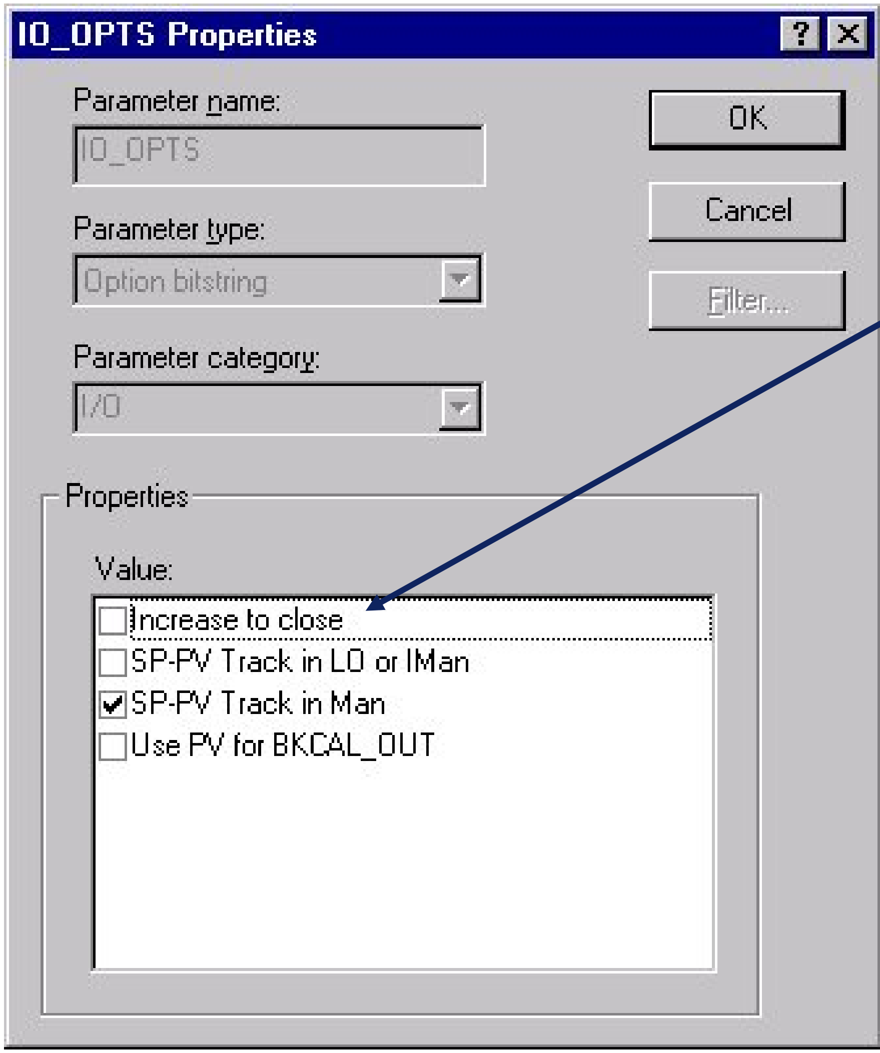
Analog Output Function Block



AO Setpoint Rate Limits

- The AO setpoint rate limits apply even when the block is in CAS mode
  (as well as Auto).
- This feature may be use to limit the maximum rate at which a valve is change in automatic control.
- BKCAL_OUT status is set to limited if changes in OUT are limited.
  This prevents the PID from winding up under these conditions.

I/O Options in the AO Block

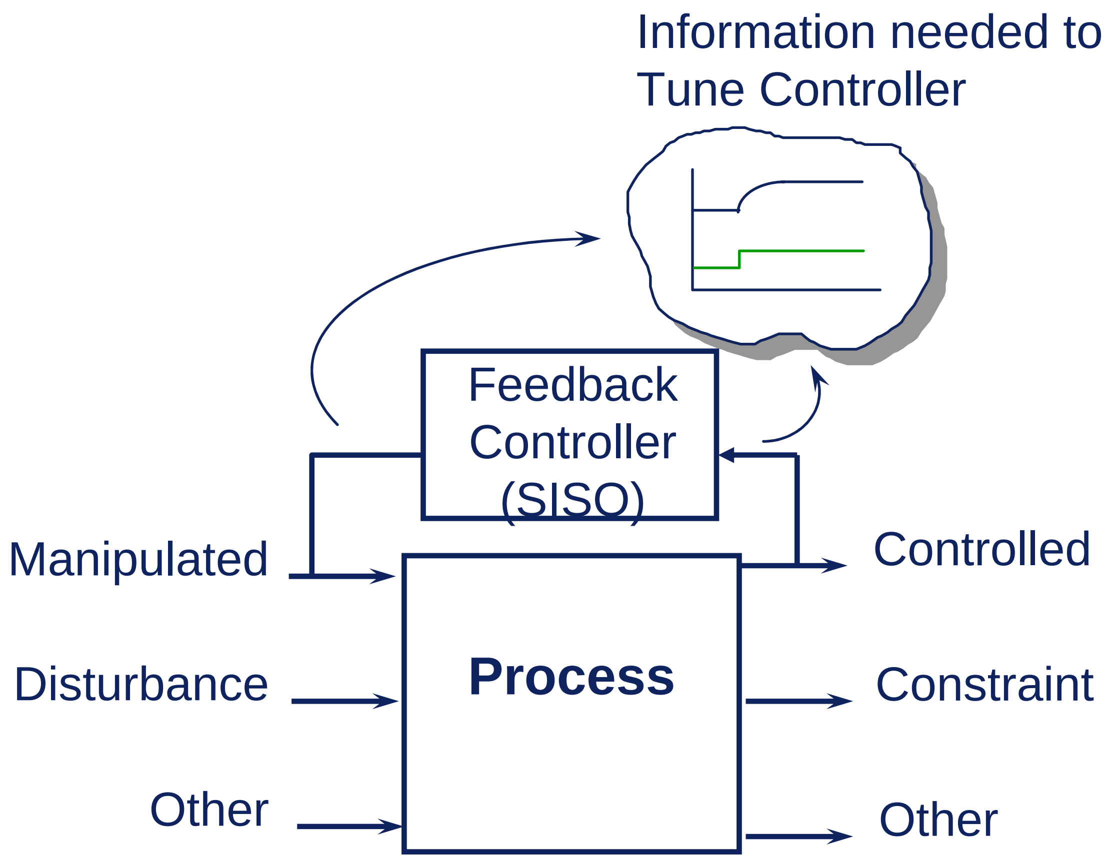


- The Increase to close option should be ***set to account for field reversal*** (I/P, actuator) so that the SP value always indicates "implied" valve position.

Why Feedback Control?

- A large number of processes within industry may be characterized as having significant load disturbances.
- To maintain the control at setpoint, the manipulated parameter must be adjusted each time there is a change in the load disturbance.
- Manual control is often times insufficient since the operator not be able to respond fast enough to correct for changes in the load disturbance.
- In this case, a means of automatically adjusting the manipulated parameter to compensate for disturbances is required.

Basis - Feedback Control



- One means of automatically compensating for load disturbances is know as single-input single-output (SISO) feedback control.
- Feedback control is based on comparison of the measured value of the controlled parameter to setpoint to calculate the value of the manipulated parameter to maintain setpoint.
- The technique most frequently used for feedback control is the PID algorithm. Different structures of the PID are used to address different application requirements.

Proportional-only Control

$$OUT = K_P * Error + BIAS$$

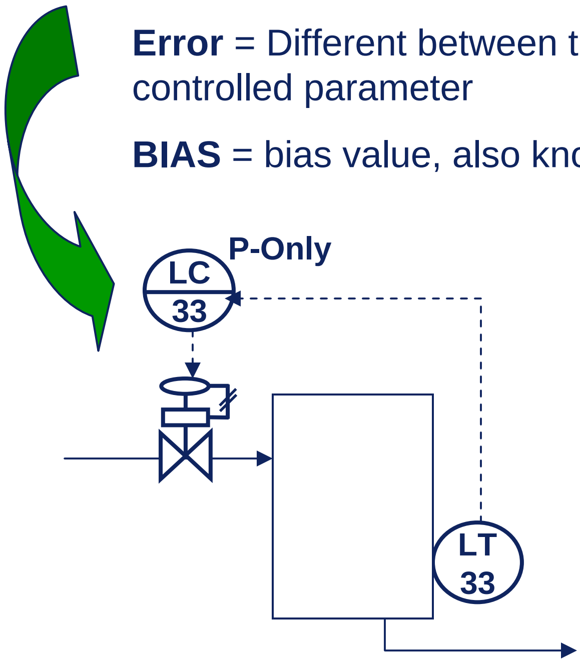
Where

OUT = Output of Controller

K_P = Proportional Gain

Error = Different between the Setpoint and the controlled parameter

BIAS = bias value, also known as manual reset



- The simplest PID structure is Proportional-only control.
- The major disadvantage of P-only control is an error offset may exist between setpoint and controlled parameter. For example, If BIAS = 0 then

  Error = OUT/K_P.
- Application of P-Only control is limited e.g. surge tank level control

PI Control

$$OUT = K_P\left(Error + \frac{1}{K_I}\sum Error\right)$$

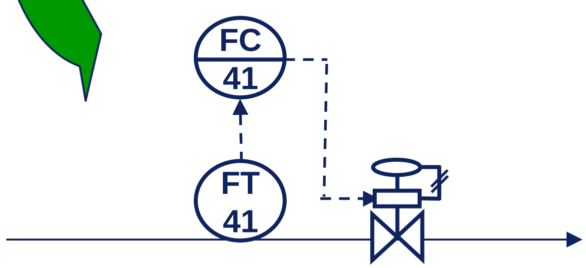
Where

OUT = Output of Controller

$\mathbf{K_P}$ = Proportional Gain

Error = Different between the Setpoint and the controlled parameter

$\mathbf{K_I}$ = Reset time, second per repeat



- By adding an additional calculation function, know as reset or integral (I) model to proportional –only control, the PI controller is obtained.
- The reset contribution will continue to change OUT until the control error is driven to zero.
- This structure of the PID is most common since it can be used to address a wide variety of applications

PID Control

$$OUT = K_P\left(Error + \frac{1}{K_I}\sum Error + K_D * Rate\ of\ Change\right)$$

Where

OUT = Output of Controller

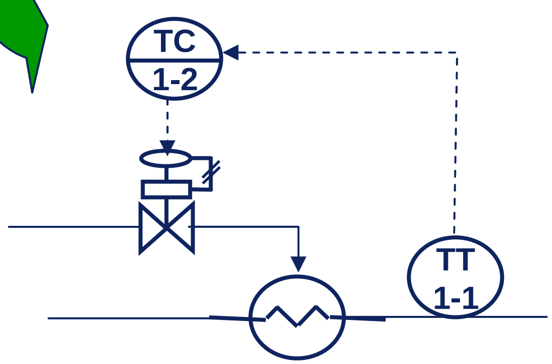
PV = Control measurement

K_P = Proportional Gain

Error = Different between the Setpoint and the controlled parameter

K_I = Reset time, second per repeat

K_D=Rate, seconds



- An additional mode, known as rate or derivative action, may be to the PI controller to obtain the PID controller.
- An additional contribution is added to the calculated output based on the rate of change in the controlled parameter.
- Major changes in load disturbances are anticipated by rate action. Thus, corrective action is taken sooner and control is taken sooner
- Use of derivative action should be restricted to processes where the control measurement is noise free.

Guideline in Selecting PID Structure

The selection of PID structure should be based on the process i.e. how the controlled parameter reacts to a change in the manipulated parameter.

- I-Only – When the response of the controlled parameter to a change in the manipulated parameter is instantaneous – the process is a pure gain.
- PI – The process can be adequately represented as a first-order lag. *The majority of industrial process fall into this category*
- PID – The process is best represented as a second-order system and the control parameter contains little noise.
- P-Only –If the process is best represented as an integrator.

Controller Action

- A direct/reverse selection is normally provided with the PID to compensate for the relationship of the manipulated parameter to the controlled parameter
  - Select ***direct*** if the manipulated parameter must increased to correct for an increasing controlled parameter
  - Select ***reverse*** if the manipulated parameter must be decrease to correct for an increasing controlled parameter

Note: The OUT parameter of the PID is normally considered to be the manipulated parameter.

Initial Tuning

	Gain	Reset	Rate
Flow	0.3	5	--
Temperature	1.3	300	60
Level	2	600	--
Gas Pressure	10	600	--

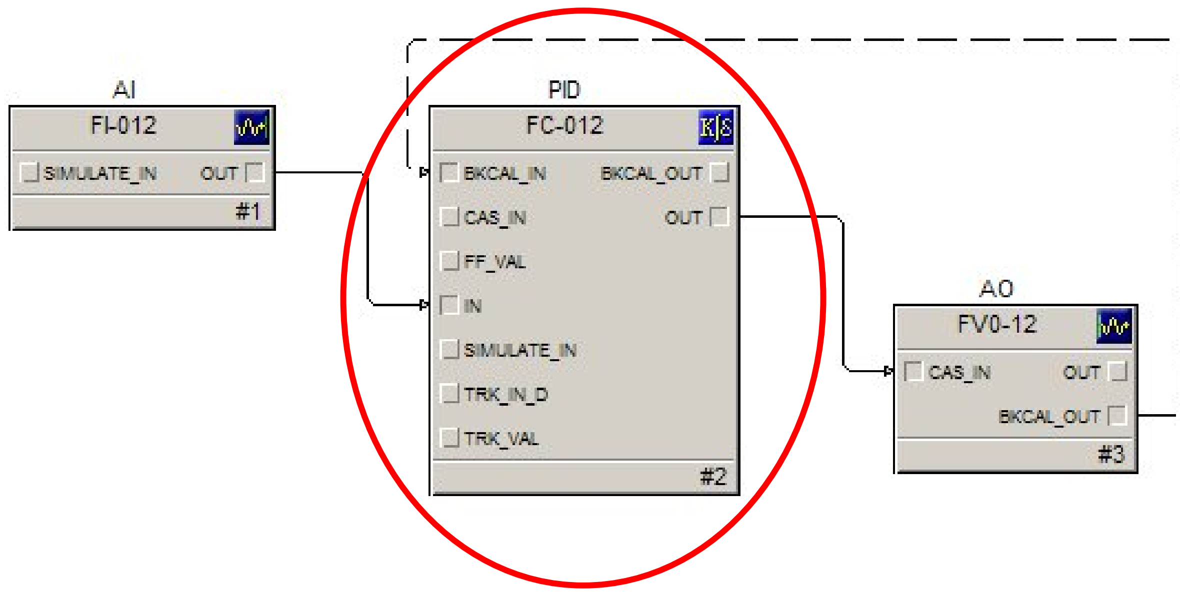
- Initial controller tuning may be used during control system design.
- The values are conservative and will result normally in sluggish response.
- Once the plant is online, the tuning should be refined based on the observed process dynamics and gain.

Simple Tuning Technique

Tuning of a PI controller applied to a self-regulating process can be quickly establish as follows:

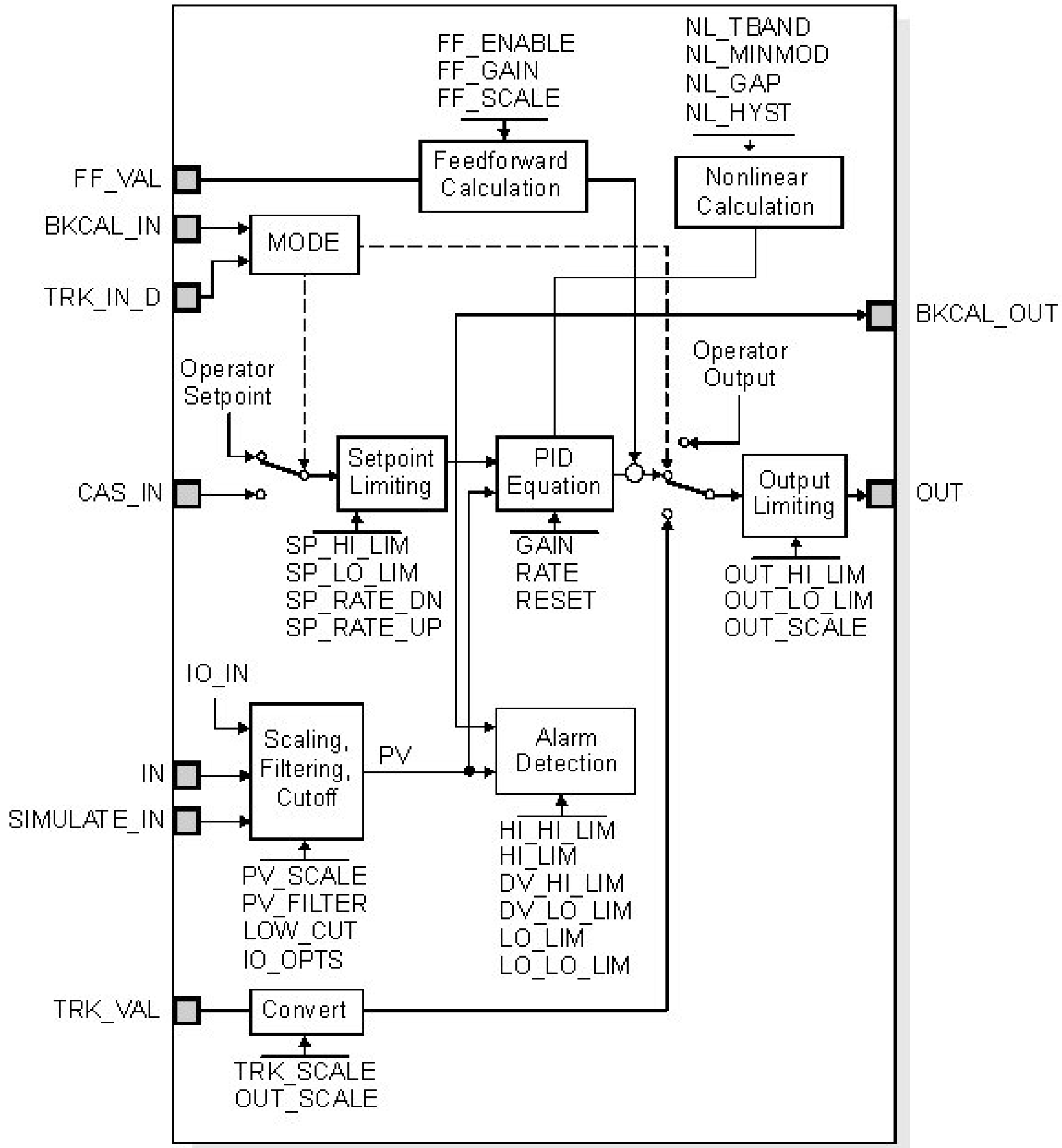
- Place the controlled and manipulated parameters on trend.
- Place the controller in manual and allow the process to reach steady state.
- Impose a step change in OUT and observe the response.
- Set the RESET to match the sum of the process deadtime plus the time constant.
- Place the loop on automatic control using conservative GAIN.
- Make small changes in Setpoint and observe the response. Adjust only the GAIN to achieve the desired response.

Feedback Control In DeltaV



- The PID function block are designed to work with the AI and PID blocks to implement feedback control.
- The BKCAL input is used to provide bumpless transfer and to communicate when downstream limits to encountered and thus avoid reset windup.

PID Function Block



PID Implementation Detailed in Books On-line

The standard form is a discrete implementation of:

$$OUT(s) = \pm GAIN_a \bullet \left(KNL \bullet \left(\frac{P(s) \bullet T_r s}{(T_r s + 1)} + \frac{E(s)}{(T_r s + 1)} \right) + \frac{D(s) \bullet T_r s \bullet T_d s}{(T_r s + 1)(\alpha T_d s + 1)} \right) + \frac{L(s) - F(s)}{(T_r s + 1)} + F(s)$$

The series form is a discrete implementation of:

$$OUT(s) = \pm GAIN_a \bullet \left(\frac{P(s) \bullet T_r s}{(T_r s + 1)} + \frac{E(s)}{(T_r s + 1)} + \frac{D(s) \bullet T_d s}{(\alpha T_d s + 1)} \right) + \frac{L(s) - F(s)}{(T_r s + 1)} + F(s)$$

For L = OUT (which is the same as OUT being unconstrained) and P = D = E the equations reduce to:

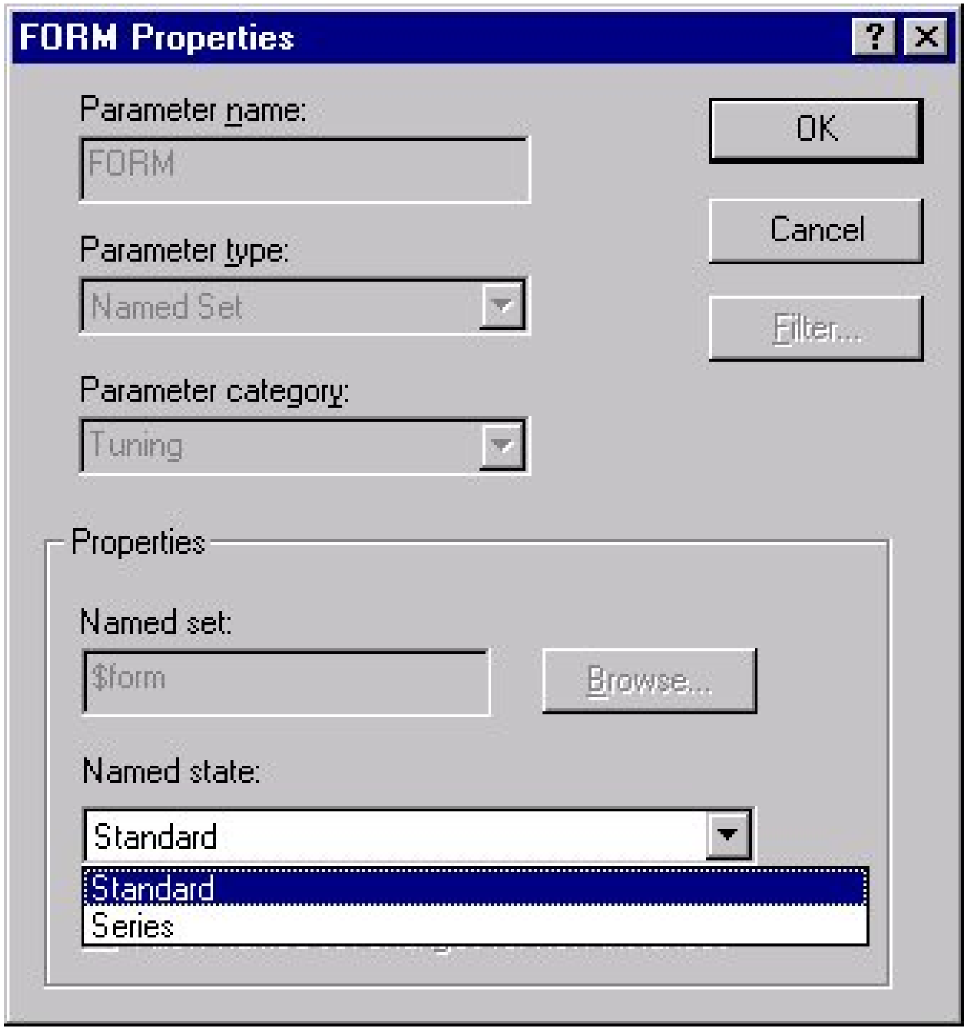
A conventional Standard PID with feedforward,

$$OUT(s) = GAIN_a \bullet \left(1 + \frac{1}{T_r s} + \frac{T_d s}{(\alpha T_d s + 1)} \right) \bullet E(s) + F(s)$$

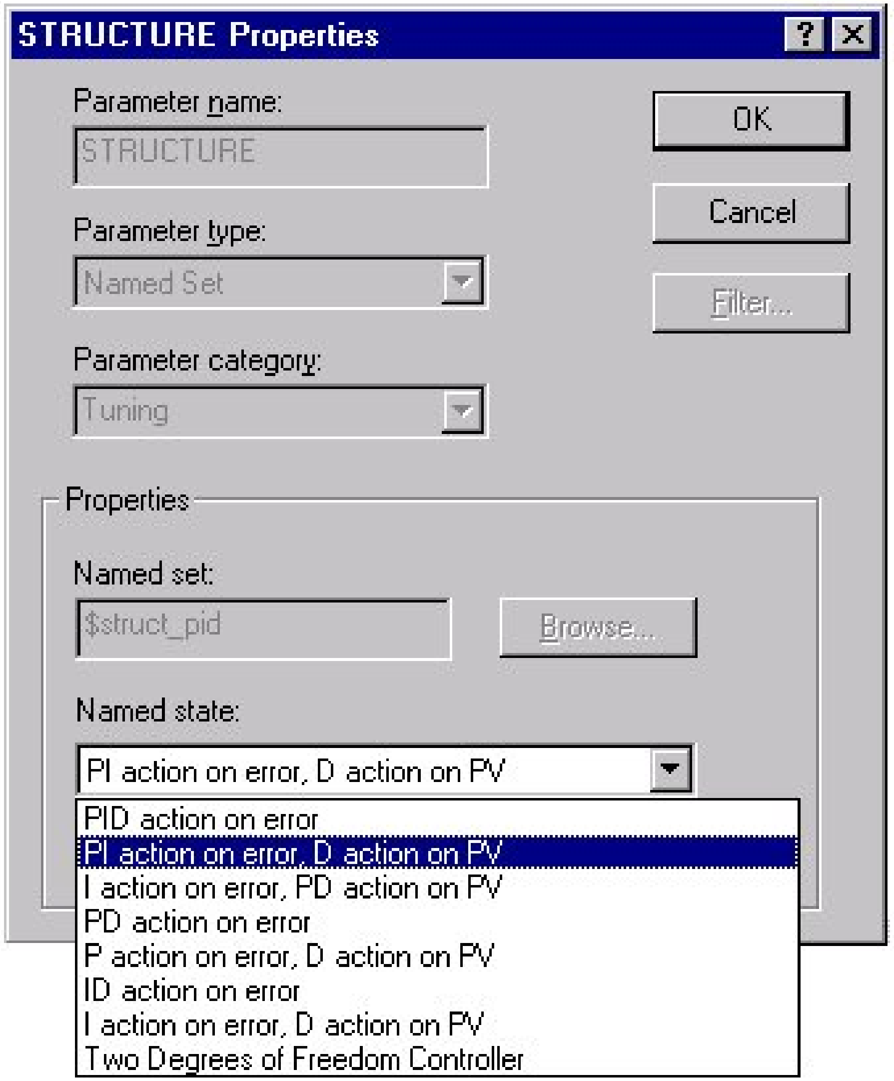
and Series PID with derivative filter applied only to derivative action, with feedforward

$$OUT(s) = GAIN_a \bullet \left(1 + \frac{T_d s}{(\alpha T_d s + 1)} \right) \left(\frac{T_r s + 1}{T_r s} \right) \bullet E(s) + F(s)$$

Selection of PID Form

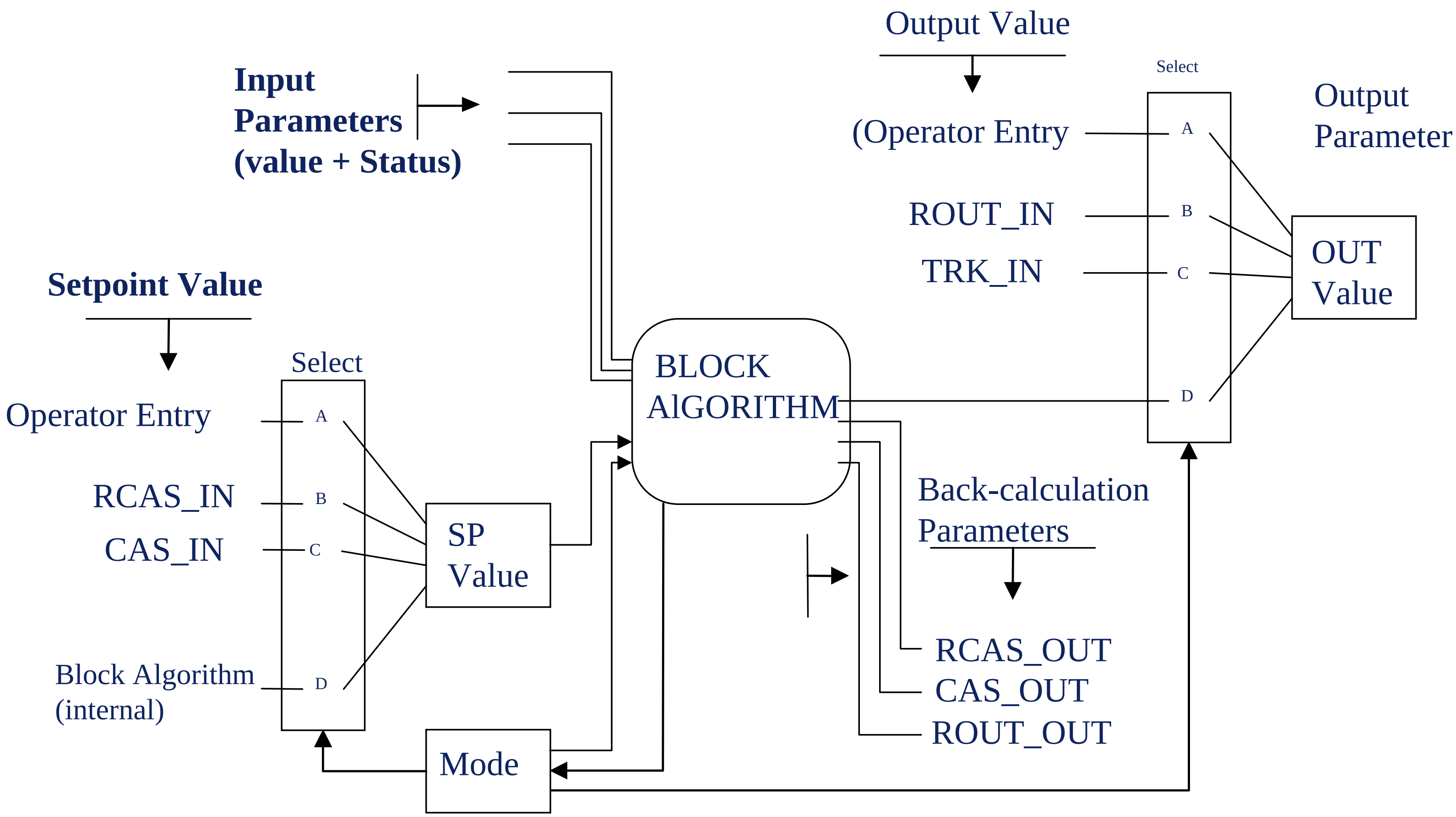


PID STRUCUTRE Parameter



- Selection are provided for P, PI, PID, I and ID.
- Using the structure selection, you may choose whether proportional and derivative action are taken on error or PV value.

Mode Determines the Source of Output & Setpoint



Supported Operator Modes

Mode	*Source of SP*	*Source of OUT*
Out-of-Service(O/S)	Operator	Operator
Manual (Man)_	Operator	Operator
Automatic (Auto)	Operator	Block
Cascade (Cas)	CAS_IN	Block
Remote Cascade(Rcas)	RCAS_IN	Block
Remote Output (Rout)	Operator	RCAS_OUT

Control and output blocks

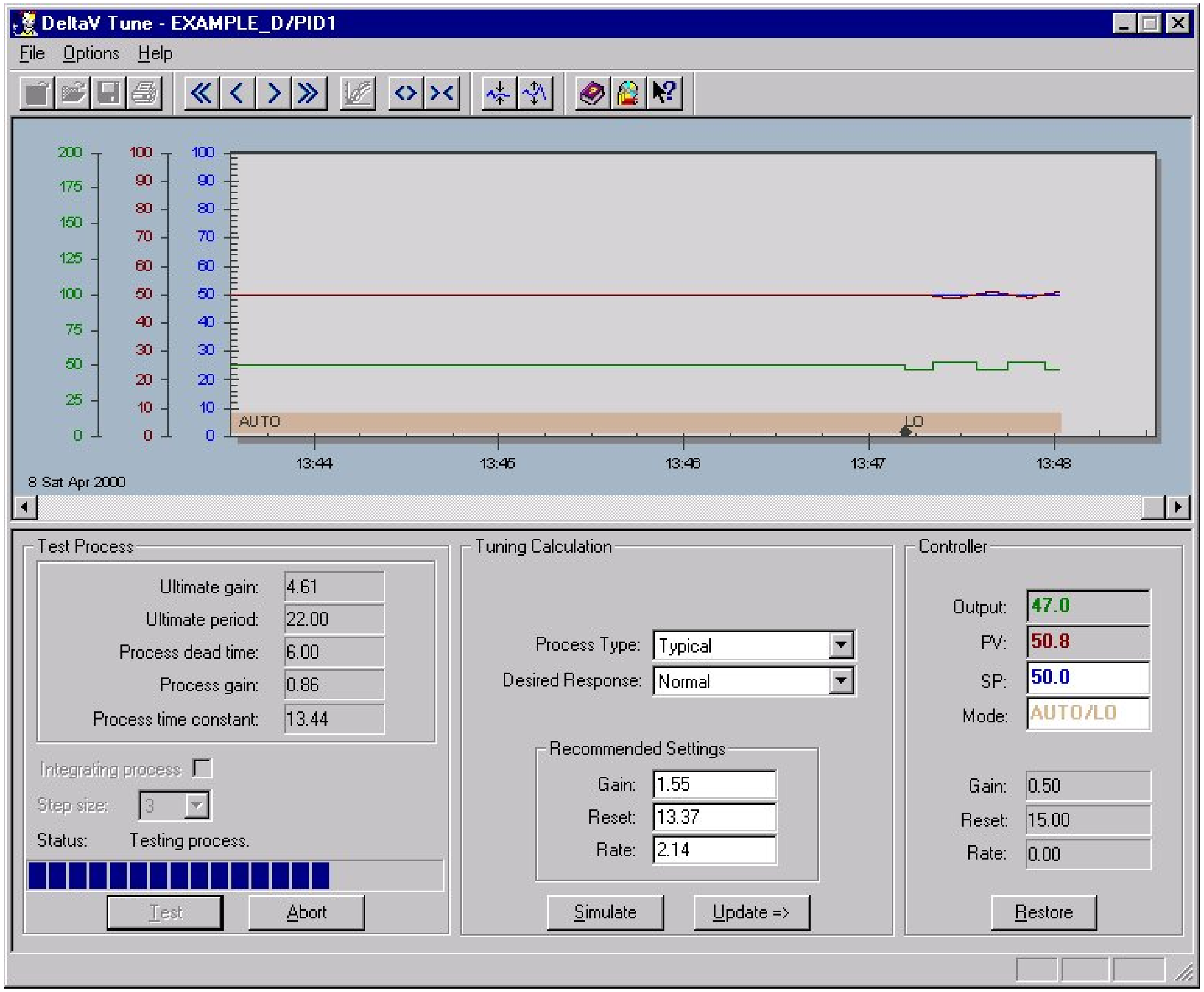
Other Actual Modes

Actual Mode	*What it means*
Local Override (LO)	Track or Auto-tuning is active and in control of the output value
Initialization Manual (IMAN)	The forward path to a physical output is broken and the output is tracking the downstream block

Tuning PID for Best Performance

- Process Identification Based on Relay Self-Oscillation Principle
- Applicable to a wide range of processes
    - Slow
    - Fast
    - Self-regulating
    - Integrating
- Immune to Noise and Process Load Disturbances
- Minimizes Tuning Time

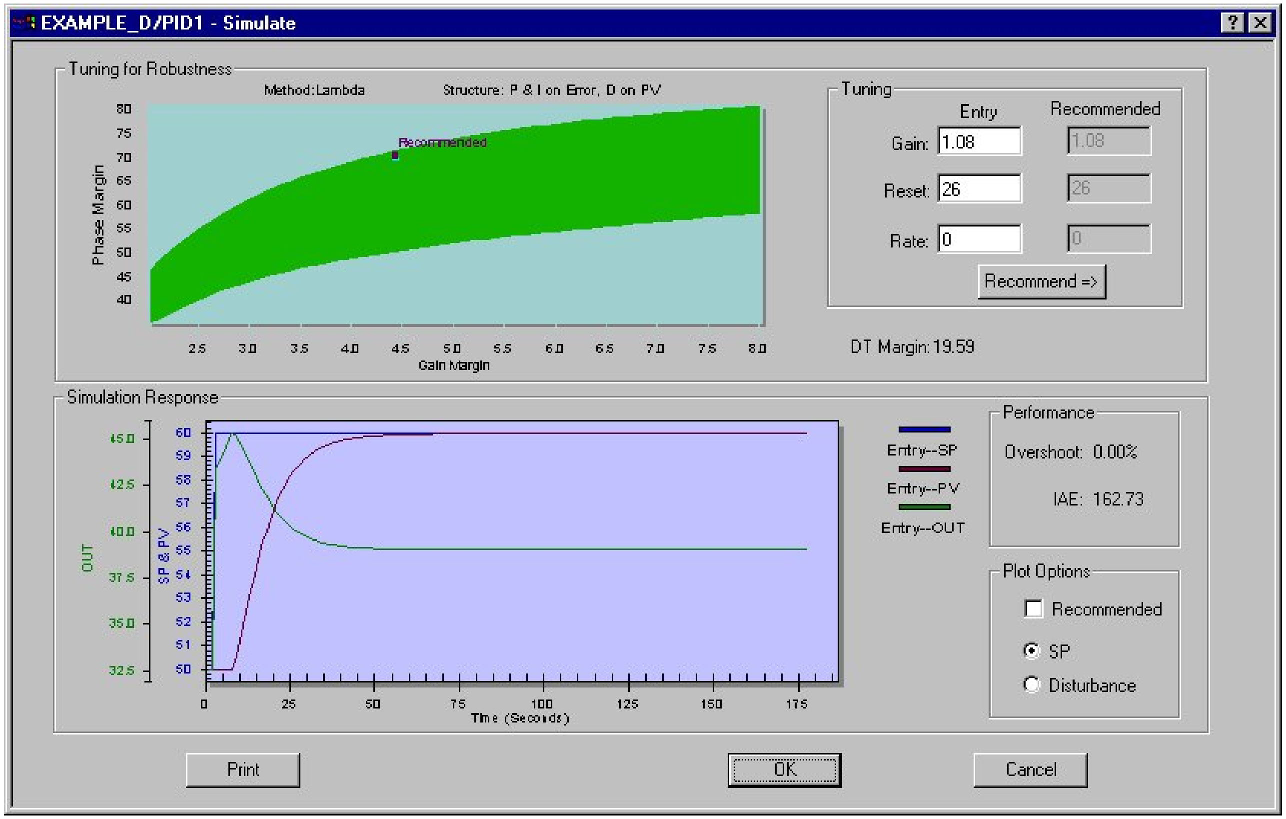
Identification of Process Dynamics



Set step size, process type, and select "Test".

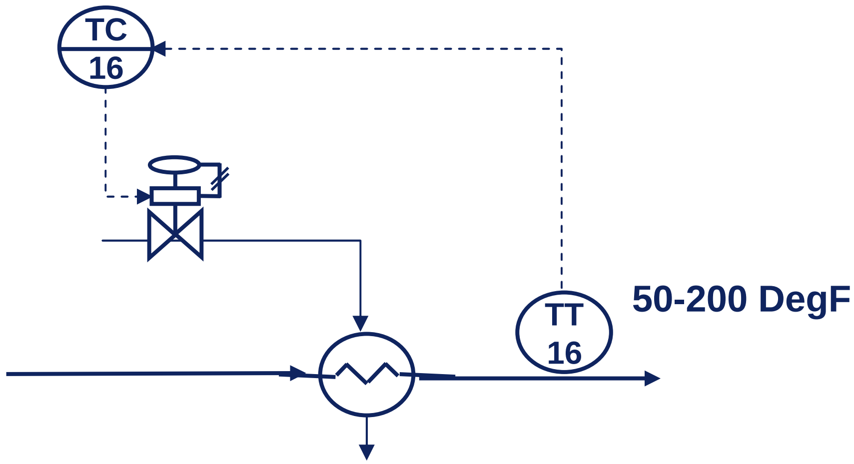
After completion of test, apply tuning recommendation by selecting Update.

Simulation of Loop Response



- By choosing Simulate, you may observe the simulated response before applying the recommended tuning.

PID Feedback Workshop – Process



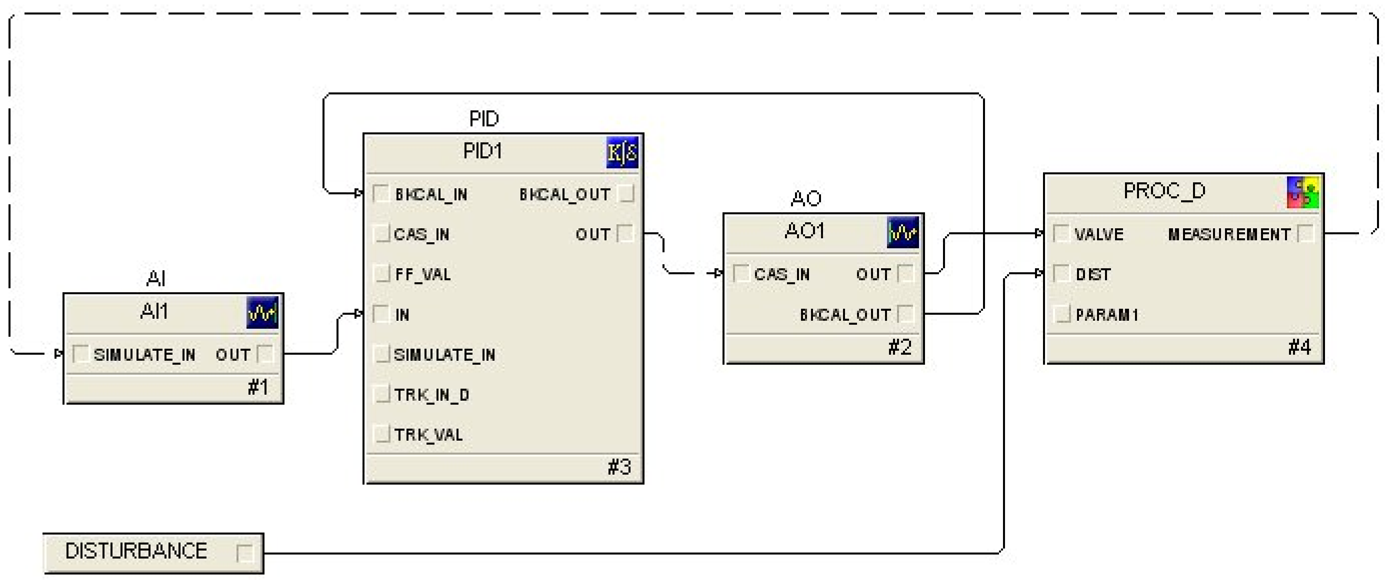
PID Feedback Workshop

Step 1. Open module EXAMPLE_D_FB in control studio and in the on-line view change the mode of the PID to AUTO and make a 5 degree step change in the SP (setpoint) parameter. Observe the control response.

Step 2. Once the simulated temperature is at setpoint, select DeltaV Tune and tune the loop. After accepting the recommended tuning, change the SP by 5 degrees. Did you observe any improvement in performance?

Step 3. Change the process type in DeltaV Tune to Temperature and examine expected response using the Simulate feature. Apply the recommended tuning (no need to re-test). Change the SP by 5 degrees. What difference in the performance did the new tuning make?

EXAMPLE_D_FB



PID
PID1
BKCAL_IN
BKCAL_OUT
CAS_IN
OUT
FF_VAL
IN
SIMULATE_IN
TRK_IN_D
TRK_VAL
#3
AI
AI1
SIMULATE_IN
OUT
#1
AO
AO1
CAS_IN
OUT
BKCAL_OUT
#2
PROC_D
VALVE
MEASUREMENT
DIST
PARAM1
#4
DISTURBANCE